Dynamic Frequency Scaling for OpenRISC processor using Thermal Sensors in ASAP7 7nm Predictive PDK

1. Team: Following students will be working on this project with equal contributions:
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2. Introduction: In modern electronics landscape, the number of transistors per chip have been increasing drastically in accordance to the Moore's law. These humungous number of transistors per chip enhance the processing capability but at the expense of increased power consumption. To further increase processing power, modern processors have multiple cores. This leads to a few cores on chip working at full throttle while some cores on chip being idle. This leads to localised areas of high-temperature on silicon called "hotspots" [1]. These hotspots can degrade chip functioning and in the worst case lead to failures. In recent years, many authors have investigated this problem and proposed thermal sensor based solutions [1], [2], [3]. These solutions aim at sensing the chip temperature and then accordingly adjusting either voltage or frequency of the core to let the core "cool-down".
   This project is aimed at developing a similar thermal sensor in 7nm predictive PDK technology [4]. The proposed thermal sensor (based on [1], [2], [3]) will be used to sense processor temperature and then adjust core frequency accordingly. We are aiming to test the sensor on OpenRISC processor [5].

3. Scope and Objectives: The scope of this project is limited to designing a thermal sensor in 7nm PDK based on a study of current thermal sensor designs. The designed sensor will then be used for DFS. Following objectives have been set by the authors for this project:
    a. **Hard objectives**:
        i. Study of effect of temperature on 7nm PDK devices.
        ii. Design of a thermal sensor in 7nm PDK.
        iii. Design of an actuator to dynamically change the frequency of processor based on the thermal sensor data.
    b. **Soft Objectives**:
        i. Show the effectiveness of sensor-actuator based design by integrating the same in OpenRISC processor and simulating the DVS behaviour.
        ii. Implement dynamic voltage scaling also along with DFS.

Hence this project will inculcate following topics studied in class:

1. Study of effect of temperature on transistor performance.
2. Design of a real world VLSI system.
3. Logical effort considerations to optimize the design.

4. References:

1. Chung et al., "An Autocalibrated All-Digital Temperature Sensor for On-Chip Thermal Monitoring", IEEE Transactions On Circuits And Systems—II, VOL. 58, NO. 2, February 2011.
2. Bhagavatula et al., "A Low Power Real-time On-Chip Power Sensor in 45-nm SOI", IEEE Transactions On Circuits And Systems—I, Vol. 59, No. 7, July 2012.
3. Chen et al., "A Time-to-Digital-Converter-Based CMOS Smart Temperature Sensor", IEEE Journal Of Solid-State Circuits, Vol. 40, No. 8, August 2005.
4. Clark et al., "ASAP7: A 7-nm finFET predictive process design kit", Microelectronics Journal 53 (2016) 105–115.
5. https://openrisc.io/